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SCALE-UP OF CARBON/CARBON BIPOLAR PLATES

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2004 DOE Hydrogen Fuel Cells & Infrastructure Technologies Program Review

David P. Haack
Porvair Fuel Cell Technology

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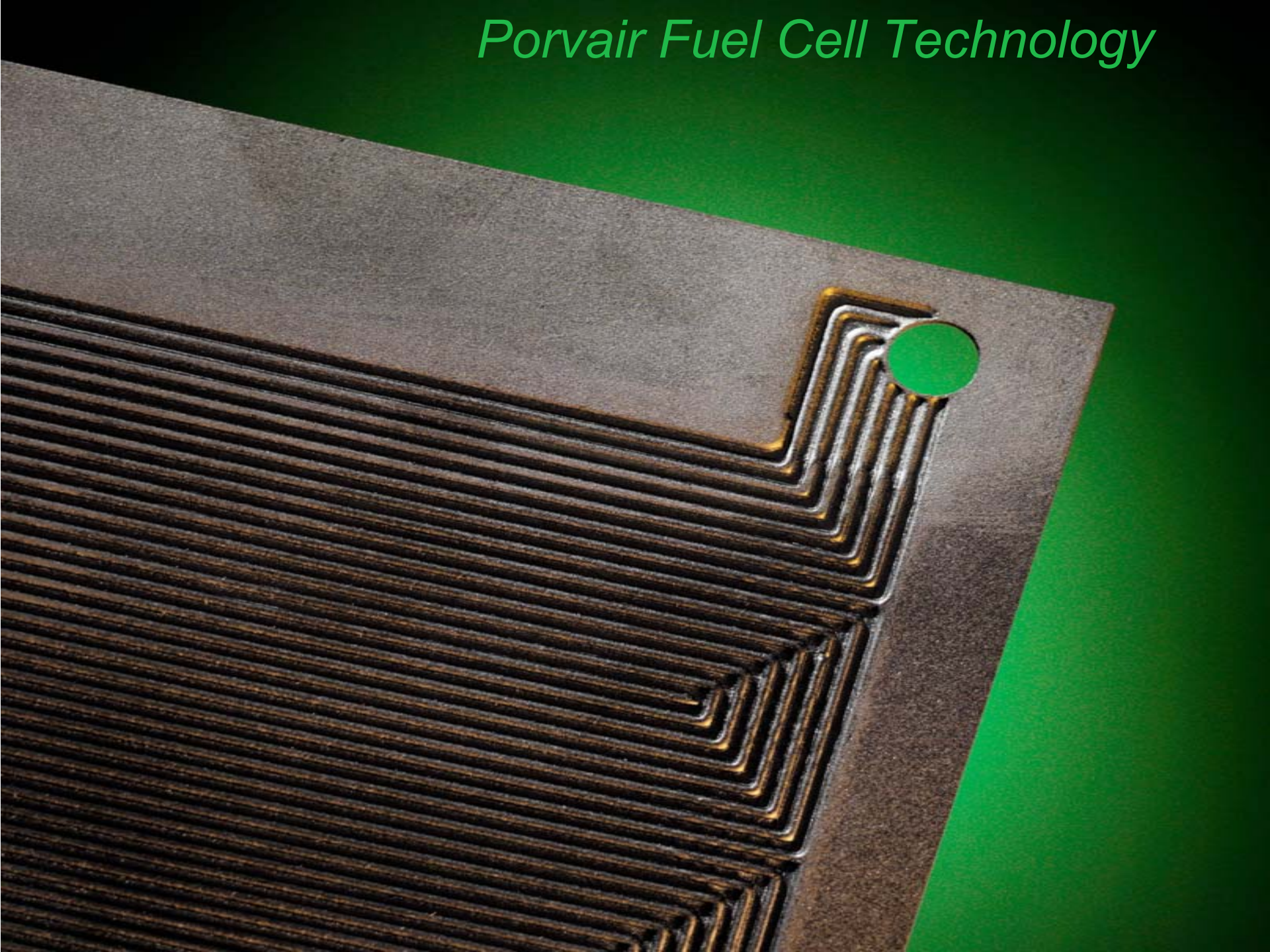

About Porvair Fuel Cell Technology

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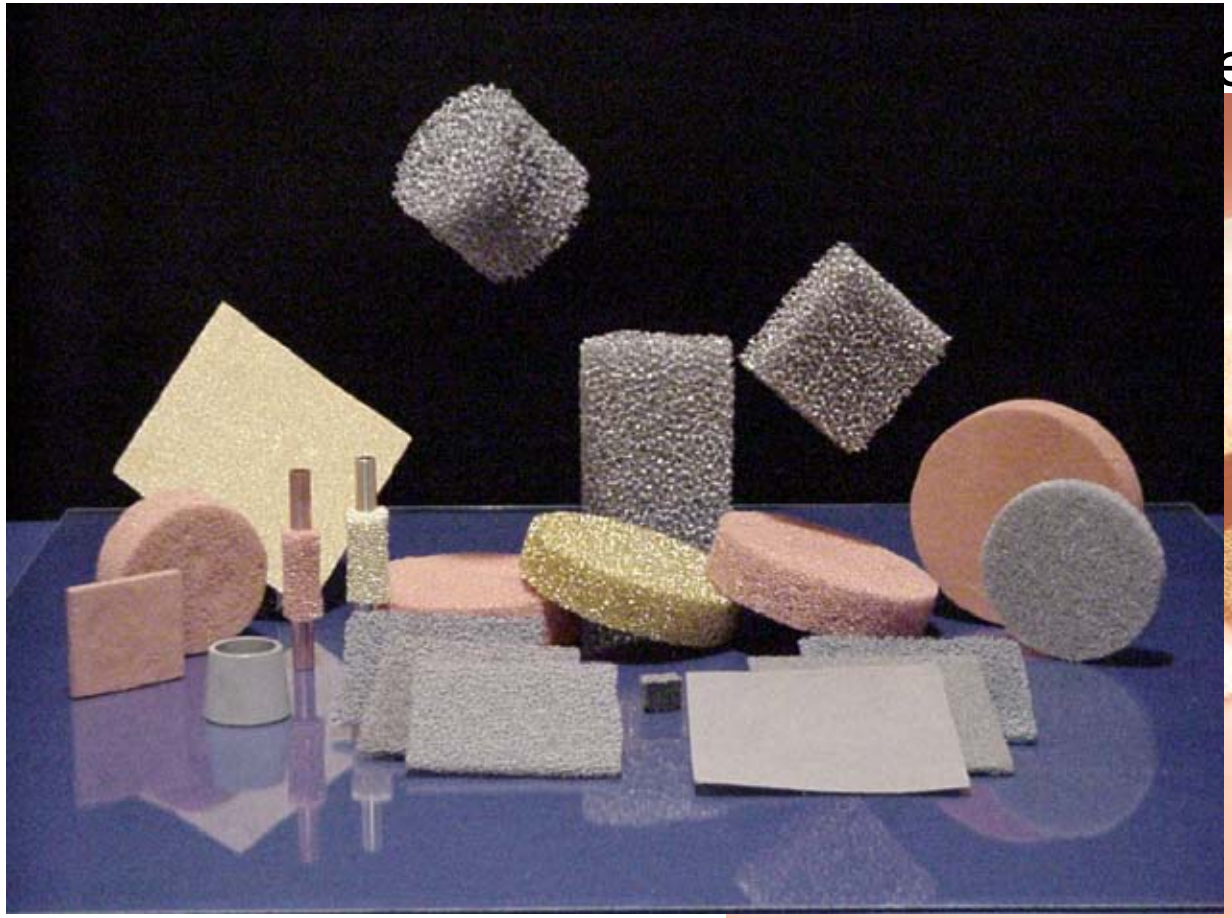
Metals



- FeCrAlY
- Copper
- Stainless Steel
- Hastelloy X
- Hastelloy C
- Inconel 600
- Silver
- Brass
- Cobalt
- Platinum
- Nickel
- Titanium
- NiChrome
- NiCoCrAlY

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DOE PROGRAM OVERVIEW

Scale-up of Carbon/Carbon Bipolar Plates

- **Develop Material and Manufacturing Method Leading to a Low-Cost Carbon/Carbon Bipolar Plate**
- **Evaluate and Demonstrate Performance of Product**
- **Evaluate Potential Cost of Manufacture**

OVERALL PROJECT OBJECTIVES

Scale-up of Carbon/Carbon Bipolar Plates

- **Develop Low Volume Carbon/Carbon Bipolar Plate Production Line**
- **Develop Incremental, Near-Term Cost Reduction Technologies for Carbon/Carbon Bipolar Plate**
  - **Near-net shape molding**
  - **Reduced-cost machining**
  - **Reduced-cost plate bonding**
  - **Net-shape molding**
- **Manufacture 10 kW Fuel Cell Sealed Plate Demonstration Stack**
- **Develop and Implement Comprehensive Quality Assurance Plan**
- **Develop Comprehensive Cost Model for High Volume Production**

BUDGET

Scale-up of Carbon/Carbon Bipolar Plates

	FY2003	Program Total
Porvair Contribution	$1,450,000	$3,338,539
DOE Contribution	$1,293,000	$3,057,000
Total	$2,743,000	$6,395,539

Pre-Pilot Operations

DOE TECHNICAL BARRIERS AND TARGETS

Scale-up of Carbon/Carbon Bipolar Plates

Fuel Cell Operating on Direct Hydrogen

Technical Barrier	Status 2003	Target 2005	Target 2010
Component Cost	$200	$125	$45
Component Durability (hours)	1000	2000	5000
Fuel Cell Performance (W/L)	400	500	650

TECHNICAL APPROACH

Scale-up of Carbon/Carbon Bipolar Plates

- **Develop Near-Term Product Cost Reductions**
  - Develop near-net shape product through product development and molding trials
  - Investigate low-cost machining processes
- **Manufacture 10 kW Fuel Cell Sealed Plate Demonstration Stack**
  - Develop material
  - Develop bonding/sealing methods
  - Manufacture product

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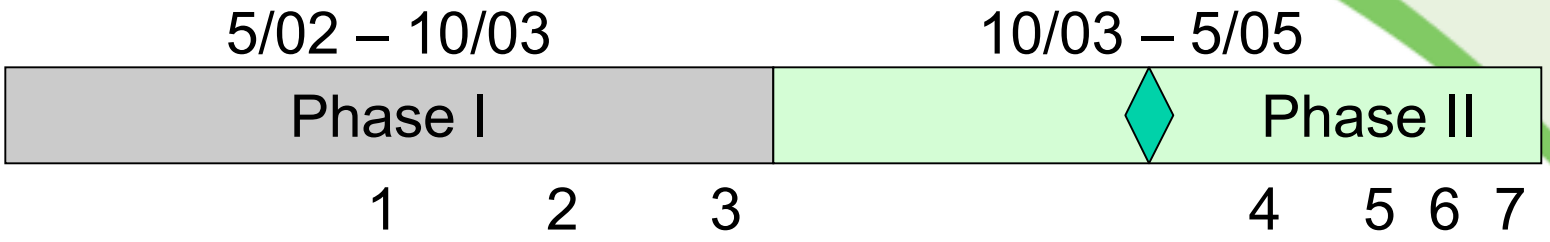
PROJECT SAFETY

Scale-up of Carbon/Carbon Bipolar Plates

- Manufacturing safety examples
  - Evaluation of raw material handling and use safety (airborne dusts)
  - Evaluation and measurement of worker exposure to off-gases generated during product manufacture
  - Improvement activities to eliminate workplace dangers (e.g., slip-prone surfaces, equipment operation and operator work procedures to minimize hazards.

PROJECT TIMELINE

Scale-up of Carbon/Carbon Bipolar Plates



Phase I – Pre-Pilot Materials and Process Development

1. Develop pre-pilot production line (5-10 plates/hour)
2. Develop materials for customer evaluation
3. Customer fuel cell demonstration

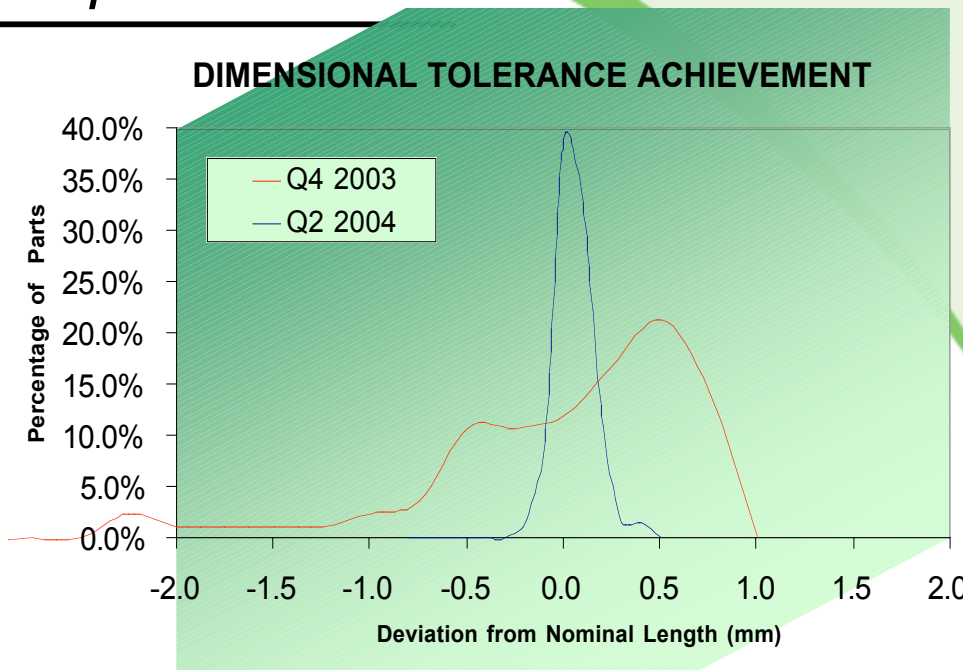
Phase II – Product Cost Reduction Development

4. Investigate and develop cost reduction technologies
5. Develop and deliver 10 kW demonstration stack
6. Develop comprehensive quality assurance program
7. Develop detailed cost model

TECHNICAL ACCOMPLISHMENTS/PROGRESS

Scale-up of Carbon/Carbon Bipolar Plates

- **Improved Product Dimensional Tolerance Achievement**
- **Molding Capability Demonstrated on Variety of Customer Platforms**
- **Excellent Product Properties Demonstrated**

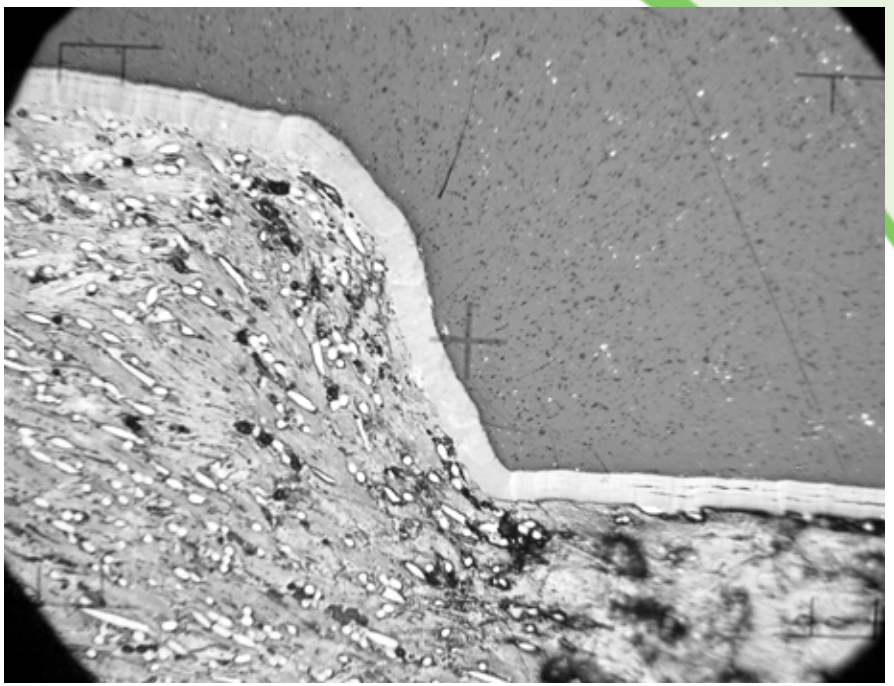


Property	Porous Plate	Sealed Plate
Electrical Conductivity (in-plane, S/cm)	300 – 600	600 – 700
Strength (4-pt bend, psi)	4000 – 5000	5000 – 7000
H_2 Permeability ($cm^3/cm^2/sec$)	N/A	$< 2 \times 10^{-6}$

TECHNICAL ACCOMPLISHMENTS/PROGRESS

Scale-up of Carbon/Carbon Bipolar Plates

- **Characterized Sealing Conditions to Produce Uniform Seal Layer and Repeatable Characteristics**
- **Developing Bonding Materials and Methods**
- **Optimizing Materials for Cost and Process-ability**



Photomicrograph of Bipolar Plate Sealed Surface Layer

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INTERACTIONS/COLLABORATIONS

Scale-up of Carbon/Carbon Bipolar Plates

- **UTC Fuel Cells**
  - Subcontractor to this program
  - Developing materials evaluation methods
  - Performing fuel cell tests on supplied materials
  - Assisting in development of quality assurance and continuous improvement processes
- **Oak Ridge National Laboratory**
  - Technology licensed from ORNL
  - Participating in product measurement methods and process evaluation

REVIEWER QUESTIONS

Scale-up of Carbon/Carbon Bipolar Plates

- **Is Process Suitable for Sealed Plate Applications?**
  - Aggressively developing sealed plate partnerships and demonstrations
  - Deliverable for program is sealed plate stack
  - Numerous trials underway with customers using sealed plate designs
- **Is Process Cost-Prohibitive?**
  - The cost of carbon/carbon bipolar plates is not cost-prohibitive. The cost of the plates is highly dependent upon the volume of production. Cost analyses indicate that long-term target of $10/kW is feasible at volumes exceeding 10,000,000 units annually.

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FUTURE PLANS

Scale-up of Carbon/Carbon Bipolar Plates

- **Remainder of FY2004**
  - Continue developing near-term low cost technologies
  - Continue developing processing capability
  - Continue developing bonding technologies
  - Manufacture and deliver 10 kW demonstration stack
- **FY2005 to End of Program**
  - Complete technology development program for low cost product
  - Complete development of comprehensive quality assurance program
  - Complete development of detailed cost analysis for product and process